ENGINEERING OPPORTUNITIES

COLLEGE EDITION, SPRING 1967

COLLEGE EDITION

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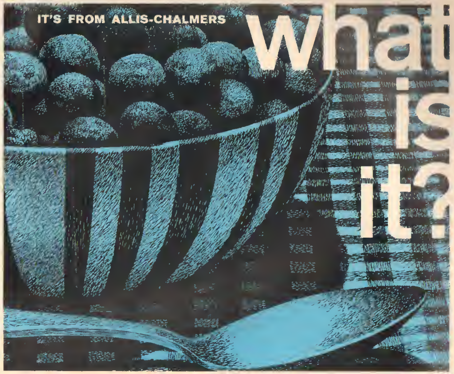

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ENGINEERING OPPORTUNITIES
1020 CHURCH STREET
EVANSTON, ILLINOIS 60201
PHONE: (312) 869-1244
New York Phone: (212) 524-0128

Norman Jacobs Norman Brodsky

San Francisco 94104
57 Post Street
Thomas Carter
Joseph Keller
(415) SU 1-5568

Los Angeles 90057
2411 W. 8th Street
Richard Faust
Richard Walker
(213) 387-4388

Boston
P. O. Box 332 (Stoughton) 02072
Gerald Green
(617) 542-1466

Minneapolis
1040 Midland Bank Bldg
Jim Ross
(612) 336-6128

New York, N. Y. W. Kendall Jones, 60 E. 42nd (212) 697-5356

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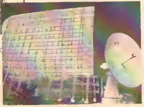

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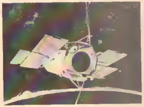

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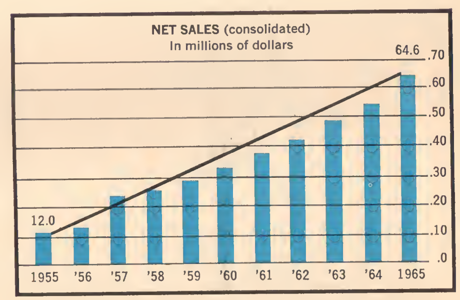

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■ Max Schulman's anti-heroic lower classman, torn by conflicting advice as to whether his stay at the university should make him "a well-rounded individual" or prepare him to earn a living was a caricature with whom it was not difficult to identify if you just hark back to your own freshman days.

In scientific and engineering education in particular, a very real battle has raged among educators for generations as to just how much concentration on the purely technical side of education is good for the long-term interests of the student and the community into which he will graduate. Within the past 10 to 15 years, developments have combined to make the question ever more debatable. The veritable explosion in technical knowledge demands more and more concentration on technical courses. In almost any discipline, four years is rapidly becoming too short a time to cover technology alone, if the student took not a single course not directly related to his major.

At the same time—within the same period—the role of the engineer and scientist in both the business and the political community has expanded rapidly. Twenty years ago, the route of progression for the young engineer or scientist was predictably *vertical*—within the confines of the research lab or the engineering department. Today, that route is quite likely to run from the drawing board to the directoral board; cutting across many different levels of administrative and executive responsibility in the course of a few years.

Four to six years of a course necessarily top-heavy with electronics, chemistry or physics may be all the educational preparation a young man gets for a career that is going to lead him from the lab or the engineering department to the presidency of his company and into important executive or advisory posts in local or federal government.

The dean of the science school may argue—with great justice on his side—that what has been learned about electronics, for instance—*since* the time *he* studied it—adds up to more than can logically be packed into a four-year course of study. Understandably, he fights for a curriculum affording added hours of technology, at whatever expense to the few remaining hours of the humanities still included in a science course.

The dean of men and the president of the university, on the other hand, tend to see this proposed curriculum as a means of spawning a generation of sociological idiots with no preparation for the sort of jobs to which technological beginnings lead today and with no background for appreciation of the sociological impact of the products of engineering and research.

That *both* these positions are substantially right is difficult to debate. Where, then, lies the answer?

There have been a number of proposals. The tech school might well be made into a four-year, undiluted course graduating a sort of super technician, with no pretense of providing an over-all education. By taking much the same course *after* two years of liberal arts (with, perhaps, a little extra emphasis on math) the student might receive a master's degree, and this would be the first degree conferring "professional" status.

"But," cries the purist, "apart from formalizing the two types of courses with some distinctive names, this is what we already have; and it doesn't seem to satisfy *anyone!*"

"But," cries the technologist and the hard-pressed recruiter for industry, "all *that's* going to do is add two years to the lead-time involved in producing the engineers that we need *now*, not six years from now!"

"But," screams the irate parent, smarting under the necessity for squeezing a couple of thousand dollars per semester out of a tight-stretched budget, "the kid is going to be middle-aged before he earns his first dollar!"

Or, it has been proposed that the basic four-year science course be revised to provide a firm foundation of science *and* humanities on which graduate studies can be used to build professional stature in some—virtually *any*—specific technological discipline.

This might produce a bumper crop of "well-rounded individuals" and thus satisfy the purist, but it still won't do much to allay the complaints of the others quoted above. After four costly years, the hard-pressed parent will find himself with a child so "well-rounded" that he can't earn a living at *anything* without two to four more years in some form of specialized course. The industrialist and his recruiter will find the undergraduate school as sterile as today's junior highschool as a source of sore-needed junior engineers and scientists.

Using the "mandala," an ancient artistic device common to far-eastern civilizations, Artist Allan Dougherty of TRW symbolically represents the nuclear atom of the human psyche and the multi-faceted character of the human mind. The mandala (the Hindu word for "magic circle") is used in many eastern civilizations by the individual seeking to explore his own unconscious with the goal of forming a balanced and harmonious relationship with the Self. Educators, seeking to balance technical education with the humanities during an explosion of technical knowledge may see in Dougherty's creation the long-sought "well-rounded individual."

Robert W. Balluffi, a professor in Cornell University's department of materials science and engineering, Ithaca, N. Y. (left), transmits course in physical metallurgy to scientists and engineers at the Sylvania division. Using an electronic pen, he draws diagrams and writes words and other graphics which are transmitted over telephone lines for display on a television monitor in the Towanda classroom 55 miles away. His voice is carried at the same time to a speaker system. Students may ask questions by pressing an indicator button in the classroom. This activates one of the "question" lights on the instructor's console. By depressing the switch under the activated light (as shown), he can talk with the students. The system, which was designed to help meet the rapidly expanding needs of modern education, was developed in Bedford, Mass., by Sylvania's Commercial Electronics Division.

And the community may begin to find that the science grad is not even an expert in his own field; hence not to be considered as either executive or advisor, even with skilled direction. A politically and sociologically "naive" Oppenheimer could be of incalculable value to a *technologically* "naive" government; but one may logically wonder what a "well-rounded" Oppenheimer would have been able to contribute. Which four hours of physics could he have sacrificed for History of Civ and still have been able to make his vital contributions?

Are we, perhaps, trying to *mass-produce* Aristotles and DaVincis—the sort of men for which Nature herself finds the pattern only once or twice in a millenium? And, if we *are*, is that too wild a dream? How many potential Leonardi went to their graves recognized only in the one field to which they had been *exposed*? Or, perhaps, totally unsung because they had never been exposed to the *right* field?

Without even thinking of how to restructure education, the universities already have their problems in terms of how to give—most efficiently—*today's* standards of education to the greatest possible number of students.

The school's best instructors may not even be on campus; they're across town (or perhaps across the country) working on a government research task, or in Washington advising a cabinet officer or congressional committee. Or they may be on campus but tied up full-time writing reports and proposals which may bring in the research grants needed to keep the graduate school afloat.

For the research grant is not just a status symbol to most universities today—it's a way of life! With "physical plant" investment per *undergraduate* student getting up into six figures (and for each graduate student, into seven figures in many schools) neither state funds nor endowments can keep a big school above water. A bare half-dozen grad students in nuclear physics, for instance, may need a computer complex (or a commanding amount of shared time on one) plus a particle accelerator and a nuclear reactor each priced well up in the millions.

How does the university provide either the top-flight instructors or the expensive hardware required to make attendance there worthwhile to the student or the community?

One answer gaining considerable impetus is the graduate consortium" approach. Under this approach, a number of universities may each surrender the scholastic dream of being "all things to all men" and make the best of the faculty talents and physical facilities of each university available to graduate students of all of the universities. The individual schools in a given area (perhaps involving several states) may give up the effort to maintain the faculty

An electronic "blackboard-by-wire" teaching system recently transmitted voice communications and handwriting over telephone lines for long-distance illustrated lectures at a demonstration jointly sponsored by Purdue University and General Telephone & Electronics Corporation. The new system, introduced last May, enables students (right) to receive course material with graphic material being presented on a classroom TV monitor. The instructor's voice is heard through a classroom speaker system. The handwritten information remains on the TV monitor until the instructor presses an "erase" button at his console. Students can ask questions or comment on the lecture by pressing a "question" button in the classroom. The instructor then activates a return audio circuit which permits the students to talk with the transmitting location. Up to six remote receiving locations can be operated from one transmitting console.

and facilities needed to maintain individually *good* schools of astrophysics, for instances that one may be able to maintain a *superlative* school to which the students of all are welcome.

While the economics of this approach are conspicuous and convincing, it has not been sold anywhere without some pains. The consortium technique, however, is helping schools in many areas to minimize individual investment in overlapping facilities as well as to make the services of top-flight educators available to far more students.

Another approach to the problem of faculty shortages lies in increasing use of electronic media to permit one highly qualified lecturer to reach students in scattered locations without resorting to the "circuit-rider" technique. Rather than lecturing at several schools on successive days, he may now lecture at several schools simultaneously via closed-circuit television and, through an associated phone circuit, be able to question—and be questioned by—students at any of the locations individually.

While closed-circuit TV is, today, hardly a novelty even in the highschool, it has usually lacked the all-important capability of permitting the student to ask, "Professor, precisely what did you mean by your statement that . . .?" By adding the phone channel, most of the advantages of "presence" are regained.

While neither the consortium nor the closed-circuit seems likely to provide all the answers to technical education—most specifically not the answer to the design of any curriculum short of a "life sentence" which will satisfy the wishes of all concerned—each probably will be a lasting force in education if only for the one or two problems for which it does present a partial answer.

A commuter trip to another near-by campus or a flip of the switch to the proper channel may go far toward making available the talents of an instructor which you might otherwise miss; but neither adds a single minute to the 168 hours in the student's own week. If Moses, Plato and Saint Peter were all lecturing six days a week on campus, it would not provide any answer to how today's tech student could fit their courses into his schedule!

The only real answer may well lie in an engineering or science course involving two years of "junior college" type Liberal Arts & Sciences studies followed by at least three and possibly four years of concentrated technical courses. As noted earlier, this is not likely to find anything like universal approbation among the many people concerned; but it may well result in a lot more engineers and scientists who fit more closely the pattern required by their own best interests, those of their employers and those of their community. ■

About 330 BC, Alexander The Great rigged a crude diving bell and descended to a depth of approximately 50 feet in the Aegean Sea. He surfaced with the sort of succint observation which marked him as "Great": "Everything down there eats everything else." Only quite recently have modern students of the ocean much surpassed the depth of either his dive or his profound scientific commentary!

MAN and the SEA

"Within 50 years man will move onto and into the sea—occupying it and exploiting it as an integral part of his use of this planet for recreation, minerals, food, waste disposal, military and transport operations, and, as populations grow, for actual living space."

The author of these prophetic words, Dr. F. N. Spiess, is the head of the Marine Physical Laboratory of the University of California's Scripps Institution of Oceanography at La Jolla, and may therefore be presumed to know whereof he speaks.

To anyone who observes the eddies and currents of science, it is quite clear that man's move to the sea has already begun. Interest in underwater technology is today at an all-time high, and each year more and more young scientists and engineers are being attracted to the glamor which today attaches to the exploration of "inner," rather than "outer," space.

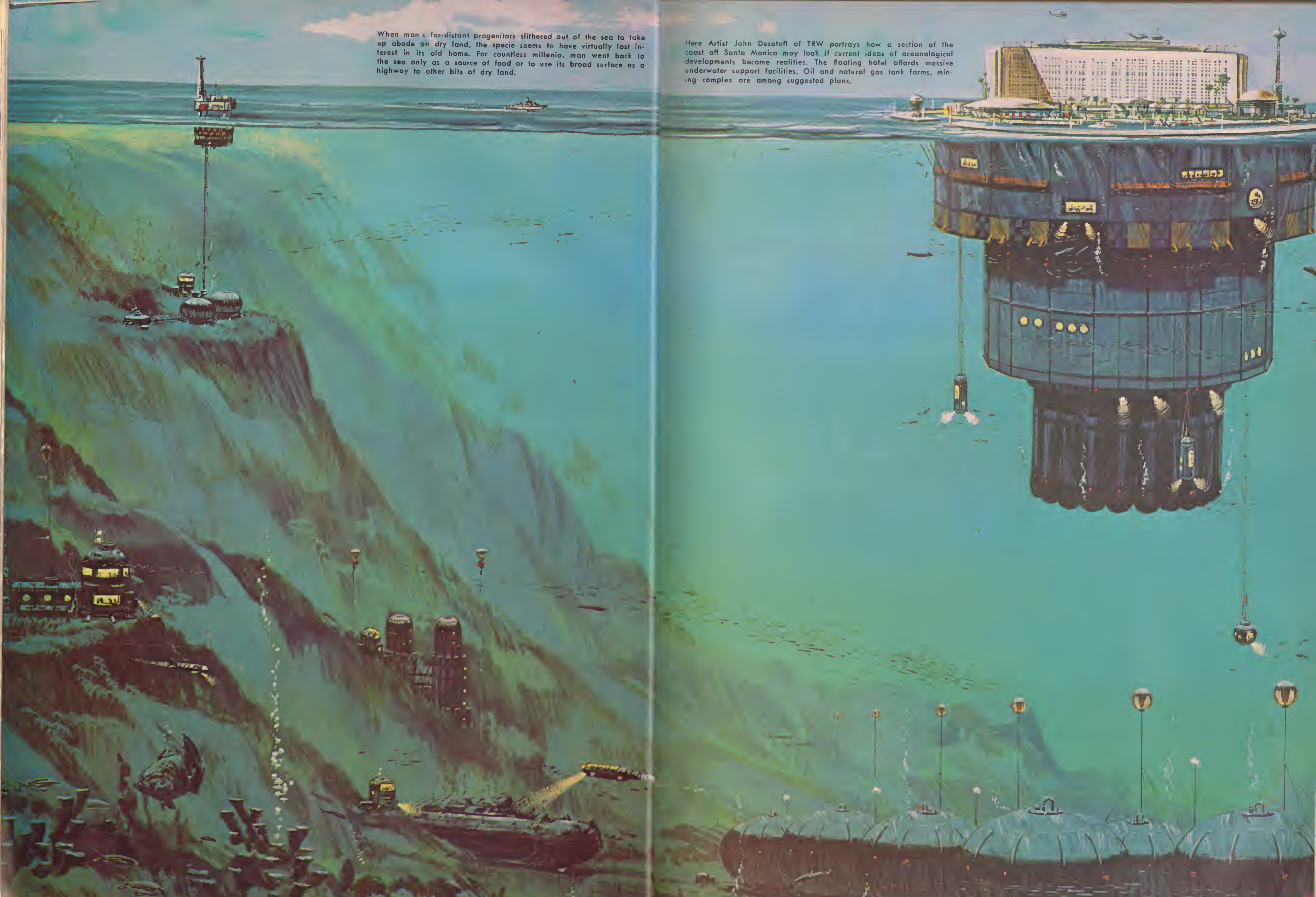
Moreover, as Arthur C. Clarke is fond of noting, scientists are all too often prone to *under*estimate, rather than *over*state, what man is capable of doing. There is little doubt in the minds of Jacques-Yves Cousteau, Scott Carpenter, and other Aquanauts, as well as oceanographers, that Dr. Spiess is being conservative, and that man will be living on or in the sea long before 50 years have gone by.

To make their point, they note simply that pressures on earth (or at least that part of it which is land, rather than water) are already such as to force man to move from the land onto and into the sea in the very near future, particularly since such a move can be accomplished much more readily, and much more rapidly, than the only other alternative—a move into space.

With the earth's population expanding more rapidly than at any time in history; with living space available only in limited areas and at a high premium; with the air over our larger cities rapidly becoming unbreathable and the water undrinkable; and, with the food that can be harvested from the land already inadequate to support even the world's present population, man's move to the sea—and into space as well—is inevitable.

It has frequently been stated that underwater technology is nothing more than oceanography put to practical use. Faced with the realization that exploration and exploitation of the sea is today of such urgency that this effort requires a priority equal to that of the national space program, the United States is now spending about $135-million annually on underwater research, and this figure is expected to rise to about $350-million by 1972. Spending during the 1962–1972 period is expected to total $2.2-billion, and could conceivably go higher than that.

As an example of the concern the Government feels about this field, it's interesting to note that Congressional interest has increased to a point where there are some different 40 committees and subcommittees involved with the authorization of expenditures by some 20 different agencies on oceanographic research and technology. In addition, there are more than a dozen bills dealing with underwater programs before Congress.



When man's far-distant progenitors slithered out of the sea to take up abode on dry land, the specie seems to have virtually lost interest in its old home. For countless millenia, man went back to the sea only as a source of food or to use its broad surface as a highway to other bits of dry land.

Here Artist John Desatoff of TRW portrays how a section of the coast off Santa Monica may look if current ideas of oceanological developments become realities. The floating hotel affords massive underwater support facilities. Oil and natural gas tank farms, mining complex are among suggested plans.

SOME BASIC FACTS ABOUT THE SEA

It might be well to begin this review of underwater technology by recalling some basic facts about the oceans. To start with, they are large, covering about 71% of the earth's surface, and deep, with a mean depth of 3,800 meters (compared with a mean land elevation of only 840 meters). At some points in the Marianas Trench in the Western Pacific, depths of almost 11 kilometers have been recorded. However, by far the biggest portion of the oceans reaches a depth of only 3 to 6 kilometers, and underwater exploration at present tends to concentrate on depths of less than 300 meters, which include all the continental shelves, and depths near 6 kilometers.

The oceans are also generally dark, although optical properties tend to vary considerably because of the presence of large quantities of tiny plants and animals, and rather chilly, with a uniform temperature of about 39°. Sea water is made up of about 86% oxygen, 10% hydrogen, 2% chlorine, 1% sodium, and minute quantities of magnesium, sulphur, calcium, potassium and seven other elements. The question of why the sea is salty is answered by the fact that today's best estimates indicate it contains approximately 5×10^{16} tons of salt.

One point everyone seems to forget about the oceans is that while we talk of this ocean or that ocean, there is really only one huge ocean on earth, and this ocean embraces every body of water found on maps which bears the name of ocean, sea, gulf, sound, bay or strait. All of these eventually meet in the body of water called the Antartic Ocean, which actually has three branches—the Atlantic, Pacific and Indian Oceans—flowing Northward from the Antarctic Circle.

The engineer whose job it is to build the vehicles which will explore the ocean's depths, and to provide the scientist with the equipment and instruments he must have to learn more about them, inevitably goes to the scientist before he begins to build these vehicles and instruments in order to learn what the scientist already knows about the ocean environment. The answer, by and large, is, "not much," or at least not nearly enough or as much as he'd like to know. And those answers which science can provide only lead him to more difficult problems.

Dr. Spiess has explored some of these problems in a recent article. He notes, for example, that, while the surface of the sea has understandably been better explored than its depths, we still have a good deal to learn even about this relatively accessible area. For example, the complex phenomenon of surface waves is still imperfectly understood, and, although theoretical studies in this area are numerous, and reasonable predictions of the spectrum of vertical motion and the directional distribution of wave energy can be made, actual measurements

of the directional spectrum in the open sea have been few and far between. In addition, we still know relatively little about such things as the conditions controlling heat transfer and evaporation.

Once we move below the surface of the sea, things get even more tacky. We may encounter such phenomena, for example, as internal waves—some with wave amplitudes of hundreds of feet—for which no adequate explanation is as yet available. However, Dr. Spiess points out the relative stability of this area (at least compared with the surface), and particularly of the deeper parts of the sea, has permitted fairly accurate measurements to be made of such quantities as density, pressure, sound velocity and index of refraction as functions of depth. All of these are known today to an accuracy of about 0.1% in most areas. In addition, measurements of absolute temperature, conductivity and salinity are today considered accurate to 1% or better.

One subject both the scientist and engineer would like to know a good deal more about is how the water flows horizontally. While the locations, general directions and approximate average speeds of sea currents are generally known, this information is usually available only as average numbers, and these may vary considerably in currents found at a particular time or in a particular place.

In general, it may be said that maximum current speed occurs close to the surface, with maximum speeds of 5 to 7 knots being found in the strong western boundary currents and lower speeds registered in the equatorial and eastern boundary currents.

The numerous plants and animals with which the sea abounds pose all sorts of problems both for the scientist and engineer. In addition to the damage large fish such as the shark or whale can do, even the very tiniest organisms can increase drag on an undersea vehicle, clog water systems, foul lines and even destroy certain kinds of materials. These organisms also wreak havoc on systems which use sound or light sources for communication or detection purposes. Anyone who has ever listened to sonar underwater can tell you it's an acoustical bedlam.

When we reach the sea floor, we find another group of problems. For one thing, information about its topography is rather sketchy, and large portions of the sea floor have never been measured accurately, although acoustic techniques in use since the end of WW-II have given us a good deal of valuable information. Sampling of actual material from the sea floor, as Dr. Spiess indicates, is even more difficult, although new techniques give promise of obtaining deeper penetration. To date, only bottom photography has provided significant information on the detailed nature of the sea floor.

From what has been done, however, it appears that the sea floor is considerably more diverse than the sea itself. although within this diversity certain typical areas exist. Thus each ocean has its own ridges, plains, seamount regions and marginal deeps, as well as large areas of low relief.

The large-scale features of the sea floor are covered with sediment, thinly in some areas where flow from the continental shelves is diverted into trenches, and more thickly in others. While sediment core samples are numerous, it has not been until recently that measurements of the mechanical properties of sea-floor mud have been carried out. These have indicated that some areas are quite soft, with shear strengths as low as 10 psi, and that others, at slightly deeper levels, are in the 100 to 300 psi range.

The sea floor appears to be much harder on materials than the water above it. Bacteria and burrowing worms abound in its mud, and chemical reactions leading to decomposition of materials is more common and more rapid.

The equipment designer called upon to supply man with everything he needs to live beneath the surface of the sea for relatively long periods of time has some special problems, as well as some unique opportunities, because of the nature of the medium with which he is dealing. These problems, and opportunities, stem from the fact that the designer must learn to live with new kinds of constraints and new physical conditions. In some instances, he soon finds he may be able to turn what appear to be constraints into advantages.

Take pressure, for example. It is difficult enough and costly enough just to supply man

View of main deck of *F. V. Hunt* shows hydrophone cable running from cable tank through cable transport and over bow sheave. Cable is slack because a "hold" has been called momentarily during hydrophone emplacement. Man seated at left monitors cable for check-point markings. ITT Federal Laboratories is instrumenting the ocean floor for the weapons test range of the U. S. Navy's AUTEC complex.

An automatic, unattended oceanbottom seismograph station developed by the Geosciences department of Texas Instruments' Science Services division is moved into position for launching. Large ball at right is buoy used to mark location when the system is submerged.

with pressure-resistant housing for long voyages beneath the surface of the sea. To try to do the same for equipment which can be left unattended would be sheer folly. Consequently, the designer tends to put as much equipment as possible outside the manned cabin, which subjects it to ambient sea pressure which grows 0.45 psi for every foot it drops beneath the surface. Therefore, the designer learns little by little to build equipment that will function properly under a wide range of pressure variations.

Temperature is another factor which must be taken into account. Here, however, it is likely to work in the designer's favor in most instances, and particularly in the case of electronic equipment, since such equipment will experience relatively constant temperatures and the effects of an almost ideal heat sink.

On the other hand, the designer of acoustic equipment, as we have already noted, has some major problems, since his equipment depends on the propagation characteristics of the medium in which it is designed to operate. These characteristics can be affected even by relatively small temperature changes (one can go from the Equator to the Arctic Circle, for example, and experience changes of only about 55° in ambient sea temperatures), while diffraction effects can severely limit the operation of such equipment.

The medium itself represents further problems. Designers who have for years been working in air, which at atmospheric pressure is a dielectric, suddenly find themselves working in sea water, which is not only a very good conductor, but is also an electrolyte with about 50 dissolved elements in it. This means that even a small current leak could very quickly prove disastrous, and all electrical equipment must be ungrounded to prevent electrolytic action. Insulation must be designed not only to keep one conductor from touching another, but also to keep the water itself from touching the conductor. Corrosion and the effects of marine life are other worries. Finally, the medium's spectral characteristics are quite different from those of air, with even the lowest commercially used electromagnetic energy (30 kc/sec) attenuated 1 db every 30 cm. However, using acoustic energy, attenuation may vary from less than .01 db per mile to several hundred in the cycle and megacycle range.

The two fundamental things which are today hampering man's progress in conquering the sea are his inability to communicate with other men beneath the sea and with men on the surface, and his inability to see under water. These are the two major challenges which engineering faces as man strives to utilize space for his own benefit.

Communication beneath the surface of the sea is no easy matter. Since the attenuation of acoustic signals is far less than that of electrical energy, the underwater telephone would appear to be the best means of underwater communication. Unfortunately, even its range is rather limited, and subject to considerable variation with temperature. Furthermore, obtaining large quantities of data with the small bandwidths available in acoustic systems is no easy matter. Also, transit time is a problem, since sound moves through water at a speed of only 6,000 fps.

Seeing underwater also presents some major problems. Direct observation of the environment is limited because of the attenuation of light in water and backscatter due to particles. As a result, direct horizontal observation at depth ranges from zero to 200 feet, with maximum usable distance under perfect conditions estimated to be about 50 feet. While some work has already been done on electroacoustic imaging, a good deal more is required before man will actually be able to "see " underwater.

While the problems of this dense, opaque medium, with physical characteristics so startingly different from those of air, at times appear insurmountable, progress is being made and will continue to be made as man begins to explore the sea's third dimension.

UNDERWATER VEHICLES

What kind of underwater research vessels do we need, and how will they be built? It is now clear that, despite the major effort the U.S. is making in this area, many problems still exist and it is likely to be some time before oceanographers are provided with a sufficient number of deep-diving submersibles to perform all the tasks they would like to carry out.

As Astronaut–Aquanaut Scott Carpenter has noted (in an address reprinted on page 50), the parallels between the underwater exploration program and the space program are striking. In both instances, for example, we find the use of both manned and unmanned vehicles; the requirement to live and work for long periods of time in a hostile environment, the development of closed-cycle type systems to meet this requirement; the birth of what is virtually a new and highly specialized industry to meet these vehicle and equipment needs, etc. . . . The aerospace industry is well aware of its capabilities in this area, and is already quite active. Official recognition of the need for the systems competence of developed by the aerospace firms is seen, for instance, in the selection of TRW Systems to integrate the entire ASW effort. In fact, it's now estimated that underwater technology will account for 10% of the industry's total sales by 1975, and it could conceivably be even sooner than that.

(See pages 30 and 31 for listing of vehicles.)

Some of these new vehicles are already in use; others will become operational in the near future. However, even our limited operations with these vehicles have revealed some major problem areas, weaknesses and requirements for new or improved equipment and instrumentation. Among these are the development of better means of communicating with surface ships or shore installations; improved navigation systems (since data gathered by a vehicle which does not know its position accurately cannot be correlated with a known position or course); more reliable sonar, which would permit vehicle mobility in dark or dirty water; and improved power systems, since long-duration missions today are largely power-limited.

The Navy has classified deep-diving research vehicles as follows:

Class I: Designed for use at depths up to 6,000 ft.

Class II: Designed for depths from 15,000 to 20,000 ft.

Class III: Designed for the deepest parts of the sea, i.e., operations at depths up to 36,000 ft.

It's interesting to note that 16% of the ocean bottom can be reached by a Class I vehicle (and also that this area roughly equals the surface of the moon). Class II vehicles can reach over 98% of the ocean floor and, in fact, 20,000 ft. seems to be a good goal for the ideal underwater research vehicle of the near future. At present, Class III vehicles are limited to what are basically deep-sea elevators of the *Trieste* type.

The Navy has described a deep-diving research vehicle as follows: "A manned self-propelled, untethered submersible, other than an operational combatant submarine, capable of operating with a reasonable degree of safety at depths of 6,000 ft. or greater, regardless of designed mission."

Present Class III vehicles all have basically a bathyscaphe design, which means they are awkward to handle and clumsy to operate. However, they are available and have done a lot of valuable work. These vehicles (the various U.S. Navy *Triestes* and the French Navy's *Archimede)* utilize lead-shot releasable weights to sink to desired depths, and then make minor depth adjustments by releasing a flotation material (usually liquid gasoline) or taking on small quantities of water ballast. Surfacing is attained by again dropping weights.

The Reynolds Aluminum/GD Electric Boat Div. *Aluminaut*, the U.S. Navy Bureau of Ships *Trident*, and the French Navy's *FRNS-3* are today's Class II vehicles. Of these, the *FRNS-3* is a bathyscaphe—the world's oldest—and has been replaced by the *Archimede*.

The *Aluminaut* represents the most advanced positively buoyant underwater research vehicle built to date. Because the 7079-T6 aluminum alloy used in its construction cannot be welded satisfactorily, it uses 11 cylindrical sections which are bolted together and capped at both ends by a hemispherical section bolted to form the pressure hull. The three-man crew, the motor and batteries, and many auxiliary components all ride within this hull.

Trident, when operational, will represent another step forward in that it will use a solid syntactic-foam material for buoyancy in place of the gasoline used in the bathyscaphe. The foam used in *Trident,* made up of tiny glass spheres suspended in a solid epoxy resin, has a density of 44 lb/cu. ft. and can withstand pressures up to 10,000 psi.

There are many more vehicles in Class I than in either of the other two Classes. Of the dozen or so vehicles in this catagory, however, only two—the Office of Naval Research/Litton Industries *Alvin* and the Westinghouse/Cousteau *Deepstar*—are true Class I vehicles in that they are designed to operate at depths of 6,000 ft. or more.

Alvin, designed specifically for oceanographic research, is particularly interesting because it is typical of the many underwater research vehicles which will be built during the next few years. Conservative in approach, its specifications were modest and considered well within the state of the art. To meet them, it was decided to build a spherical pressure hull for the crew and control instruments, with all major equipment and machinery outside this sphere for operation at ambient sea pressures. This dead weight was then compensated for by adding an inert buoyancy material.

The steering and propulsion system are interrelated, since both are provided by means of a single large stern screw which can be rotated 50° in either direction in the horizontal plane. The system makes the vehicle highly maneuverable. Two smaller propellers, separately controlled, can drive the vehicle up or down, or, by

varying or reversing thrust, can be used to steer it.

Alvin's versatility was demonstrated earlier this year when it was used to locate the "lost" U.S. H-bomb off the coast of Spain. Both *Alvin* and *Aluminaut* were used in the search for the bomb.

There are many other small vehicles capable of reaching depths from 600 to 3,000 ft. Most of these are smaller, less advanced vehicles than *Alvin.* Among them are such vehicles as the Westinghouse/Cousteau diving saucer, *Denise;* the Naval Ordnance Test Station's *Deep Jeep* and *Moray TV 1A;* Lear Siegler's *Benthos V;* the Pennsylvania University/Electric Boat *Ashera* (Star II); Electric Boat's *Star III;* the Perry *Cubmarine;* Helle's *Submanaut,* etc. Also worthy of mention are two larger Class I vehicles which are actually conventionally constructed submarines, the Swiss *Auguste Piccard* and the Navy Bureau of Ships *Dolphin,* now under construction.

Much of what man has bothered to learn about the ocean has been part of his efforts to exploit it militarily. Here Artist John Desatoff, of TRW Systems, which holds the systems integration contract for the nation's entire anti-submarine warfare program, depicts in abstraction the military use of the seas.

There are three areas in which advances are required to substantially increase deep-diving capability. The first is development of a pressure vessel capable of going to greater depths with less weight. Use of a titanium structure in place of HY100 steel in *Alvin,* for example, could significantly increase its payload or depth. The second is development of a small, inexpensive energy source with a high power-to-weight ratio, capable of operating for extended periods at the ambient pressures of deep water. The third is

a water- and pressure-resistant buoyancy material which is lightweight and inert.

Solving these problems would go a long way toward supplying man with a truly satisfactory deep-diving research vehicle. They pose a considerable challenge to the nation's engineering community.

The materials problem is a particularly interesting one. Fiberglas, plastics and concrete are under investigation for lightly stressed enclosures capable of operating at ambient pressures. In fact, Edwin Link designed a 600-ft.-depth manned enclosure consisting of a base frame and a cover made of rubber-covered cord similar to that in an auto tire. The frame in this design could have been made of reinforced concrete, and using moldable or laid up materials would be considerably less expensive than using conventional means of submarine hull fabrication.

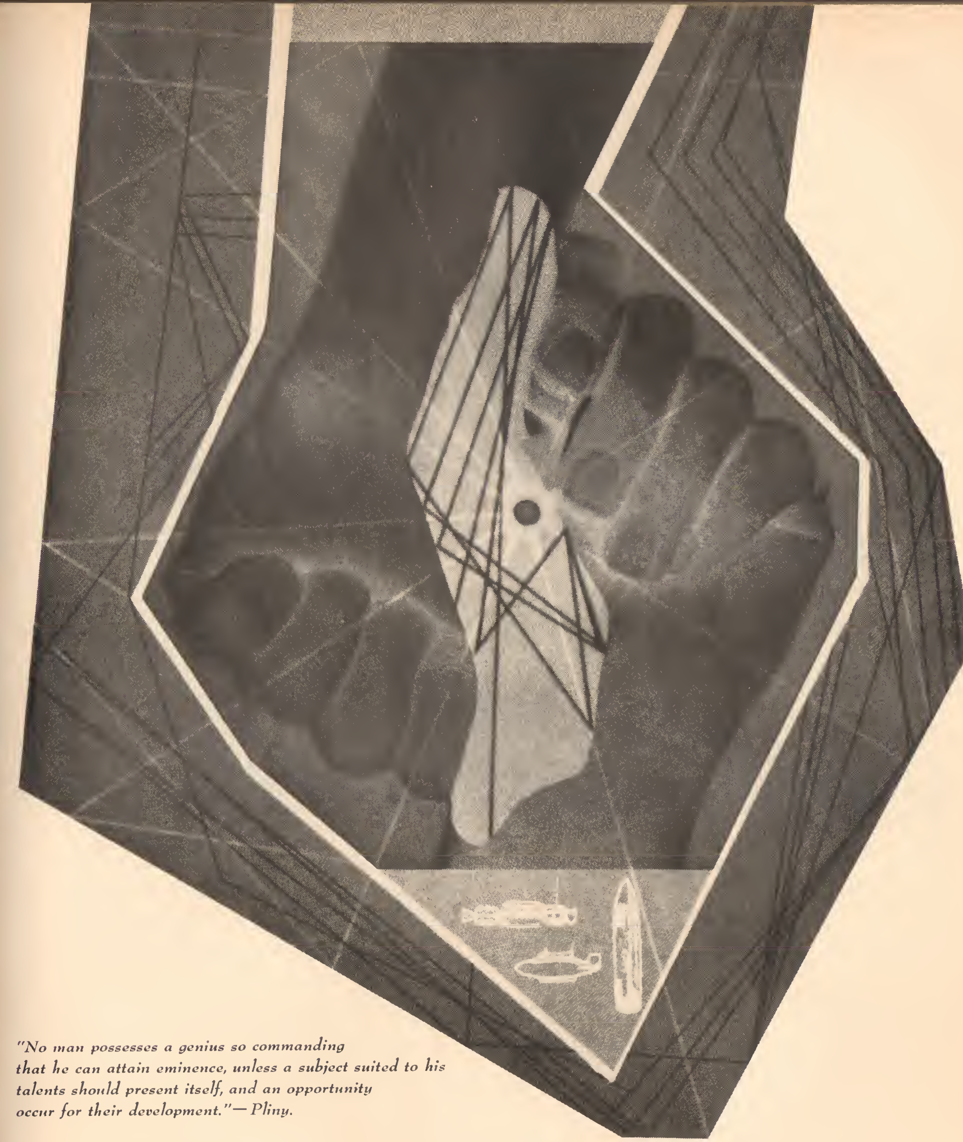
ARTIFICIAL "GILLS"

Life-support systems of greater efficiency are also required in these vehicles. Recently, interest has grown in using the dissolved oxygen in the sea as fish do. Some form of artificial gill might well reduce the amount of resupply materials such as oxygen, lithium hydroxide, or other absorbents now required. Engines operated on recovered oxygen might even make the use of fossil fuels more attractive than nuclear power when costs, operational hazards and operational complexity are taken into account.

Another interesting program worth noting is the Navy's Deep Submergence Systems Project, for which the Office of Naval Material has overall responsibility and the Nortronics Division of Northrop Corp. is the industrial coordinator. Established in June, 1964, the program is designed to provide a means for deep-water search, rescue and salvage operations. Three vehicle types are being projected, one to be used for rescue and two for search at different depths. All of the vehicles will be built on the sphere principle, and initially 40 Navy submarines will be equipped to carry the rescue vehicle, a prototype of which should be in the water late next year. The two search vehicles, development of which will follow the rescue vehicle, will be capable of operating at depths to 6,000 and 20,000 ft. respectively.

Parallel with the vehicle development portion of the project is the Man-in-the-Sea program, marked by the highly successful Sealab I and II experiment.

Sealab II was of particular significance since it provided some vital data on man's ability to live beneath the surface of the sea for long periods of time. In summing up the results of the Sealab II experiments, which ran from Aug. 28 to Oct. 12, 1965, a Navy spokesman noted that over 10,000 man-hours had been spent at 200-ft. depth, while over 500 man-hours of experience had been gained in swimming and working at depth.



From this experience, he pointed out, we had learned that:

1. Reasonably large groups of men can live for protracted periods (15 to 30 days) at 205 ft., have al arge degree of autonomy, accomplish useful work, be safely decompressed, and show no apparent serious adverse physiological or psychological effects.
2. The Navy's first experience with no-decompression excursion dives from a starting depth of 205 ft. in a saturated state to a depth of 266 and 300 ft., were successful. This represents an important addition to undersea diving technology.
3. There is a clear degree of diver adaptation to cold water as shown by interviews with the Aquanauts and by pre- and post-cold water emersion physiological measurements.
4. Adequate protection against cold water can be obtained for extended periods by the use of heated suits. Swimmers without supplementally heated suits are limited to less than 1 hour of useful work in 47–54° F. waters.
5. A degradation of work capability varying between 17 and 37% as compared with warm or shallow water capability occurs as the result of a multiplicity of environmental and psychological stress factors.
6. Improved tools and techniques show promise for salvage and other undersea work functions.
7. Based on the analysis of the overall performance of the Aquanauts, criteria can be developed for the selection of future Aquanauts.
8. The interaction between man and porpoise has shown that, to depths of 200 ft., the porpoise can be extremely useful to man-in-the-sea operations.
9. In-situ living offers a new and important methodology to scientific, biological geological ocean floor investigations.
10. Although vastly improved over Sealab I, the habitat and much of the diving equipment are still rudimentary and require extensive development to facilitate routine operations.
11. Deep-water swimmer communications and ocean-floor navigation systems require an immediate effort aimed at producing acceptable equipment for future man-in-the-sea operations.
12. A completely autonomous habitat awaits the development of reliable underwater power package and integrated complete life-support systems.

HARVESTING THE SEA

While the ocean yields millions of tons of fish each year, and the fish catch is increasing at the rate of about 8% by weight annually, it is

estimated that the catch could be increased tenfold without seriously affecting the total fish population. Meanwhile, commercial fishing craft and fishing gear grow more sophisticated and efficient, particularly in the use of modern electronics for locating large schools of fish.

It is interesting to note in this connection that some of the most advanced foreign fishing fleets, and notably that of the U.S.S.R., operate very effectively over the continental shelves of both coasts of North America. In fact, foreign fleets take almost as much fish from fishing grounds under U.S. jurisdiction as do our own fleets. In other words, this is an area in which we still have some catching up to do.

Continuing improvements in catching and processing fish will be required to fully utilize the fish supply available in the world's oceans. And the supply must inevitably be used, since fish represent an excellent source of food for many protein-deficient nations. Moreover, fish meal and fish-protein concentrate appear to constitute an economical and convenient form of sea food.

These improvements will include developments in sonar, TV, and more efficient net control, as well as investigations of fish habitats and origins. Experiments in fish farming are already under way in Japan, Russia, and these may prove to be an extremely important area of research. Experiments to date have been inconclusive, primarily because so little is known about proper environmental conditions.

THE SEARCH FOR MINING METHODS

Another area of major interest today is mining the ocean's minerals. The first cautious steps in this direction have already been taken, but the future possibilities are at this point almost incalculable. Certainly mining and oil drilling in the ocean floor constitute a new industry with enormous growth potential.

The infant industry is already spawning many special new vehicles, as well as applications for existing vehicles. Mobile catamaran rigs have been used for some time in offshore oil drilling in deep water and a goodly portion of the continental shelves can be worked from large fixed platforms mounted on long, stilt-like legs. Installations of this type are supported by a variety of small craft and larger vessels, including hydrofoils, used for transferring personnel and light equipment.

The limited amount of ocean mining which is carried out today usually employs conventional hydraulic dredges, of the type used to deepen harbor channels. However, recent years have seen the development of the so-called air lift, which gives promise of playing an important role in extracting minerals from the ocean floor in the future. In the lift, air bubbles are inserted in the lower end of a pipe and thus give the water a high flow rate. Mining systems employing

(Continued on page 64)

Commander M. Scott Carpenter who has experienced a wider variety of hostile environments than any man alive contrasts the superlative back-up of astronauts with the "mail-order" equipment afforded what he calls . . .

the exploration of "inner space"
A NEWLY-LEGITIMIZED CHILD

■ There is a small but expanding group which believes that it is imperative for the U. S. Navy to develop a broad capability for exploiting the ocean floor. There is a larger group which believes it is mandatory for this nation to explore the outer reaches of space.

I belong to both, and my experience with the two assault groups dedicated to these credos allows me to make same comparisons and draw some exclusions which are pertinent to the safe, expedient, and successful conduct of our Man-in-the-Sea Program.

The comparisons reveal, among other things, some similarities in the two endeavors, and there are more of these than the casual observer might realize. For example, we face many of the same problems in:

1. Design and fabrication of the machines, and particularly of the environmental control systems.
2. Selection and training of the crews.
3. Suit design, manufacture, and fitting.
4. Physiological and psychological studies conducted before, during, and after the experiments. These are becoming more and more important as we approach prolonged mission times.

Both must design and test hardware, and select, train, and test men, specifically for operation and use in a foreign environment. We share a common need to search for new materials and new techniques.

We both need a vast array of talent and equipment not only to do the job but also to carry on the research which is a prerequisite.

Both pit man against danger, confront him with unknowns, and both say "no" to the physical barriers that we face. Both will ultimately enrich our life on this planet.

After the first Mercury flights, the recurring question was, "What was it really like?" And we answered a thousand times, "It was great, beautiful, exhilarating, a hell of a thrill." The truthful answer is that we got up in the morning and went to work. That may be a slight oversimplification, but we were so well trained that that is what it amounted to.

Now, after the Sealab operation, the question most frequently asked of me is, "Which is more exciting, more hazardous—better? Check one."

A comparison is possible; a choice is not. There is no need to pit man in space against man in the sea. One is a superbly sophisticated, glamorous effort, and its impact has set this country on its next hundred years course. It ranks currently between God and motherhood. The other is a newly-legitimatized child represented by a nucleus of 50 dedicated men working with mail-order equipment, in marginal conditions, using outmoded techniques.

Now, when I tell you we got up in the morning in Sealab and went to work, you'd better believe it. I have never worked as hard or as long, but on the other hand, never has there been for me as much personal satisfaction as there was during the entire Sealab operation. We know we were doing a good job and there was a mood of cheerfulness and willingness to work that made everyone give his best.

A lot of this has to do with the fact that divers are a very special breed. The profession calls for more guts and motivation than any other I know. I wanted to say to them, "You're magnificent, I respect and admire you, I'm proud to be one of you." But I figured only Gregory Peck would do that.

Let me tell you what one day in an aquanaut's life is like. First, forget all you've seen of Lloyd Bridges' underwater world. Sealab waters are not like that. They are dark, and dirty, and cold. We don't relish these conditions but we realize that most of the waters of the world are not warm, clear, and inviting. And we know that these are the surroundings to which man must adapt himself and his equipment if he is to prove he can live and work in the sea.

Preparation for a dive is a lengthy process. To don the easily torn, sponge-rubber, wet suit, the knife, the watch, compass, depth gage, weight belt, helmet, face mask, flippers, and breathing apparatus requires perhaps 45 min. More time is required to assemble the tools and equipment the diver will use. Still more is required for a last-minute recap of the dive plan.

The waters in which the Sealab team operated must have been in a different ocean from that in which Lloyd Bridges dives, Cmdr. Carpenter thinks; "they are dark and dirty and cold . . . not warm and clear and inviting." Artist John Desatoff af TRW Systems captures the frigid green of the 300-ft. depths in his painting opposite. E/O gratefully acknowledges the cooperatian of the Publications Dept. of the American Institute of Aeronautics and Astronautics in-providing many of the photos used in these articles on underwater technology.

Pointing up the difference in the support accorded the astronaut and the aquanaut, Cmdr. Carpenter is seen (above) ready for the elevator ride to the MA-7 spacecraft, against a background indicative of the almost unlimited financial and technological support his space trip enjoyed. Below: Ken Conda and Wally Ross work out in the training tank with one of the principal "assistants" backing up the Sealab-II crew—a trained white-sided Atlantic porpoise!

It is necessary to do all this because, as soon as a diver and his buddy—both intelligent, cooperating, communicative human beings—step through that hatch and enter the water world, they become mute and essentially deaf. Their vocabularies are reduced to less than a dozen words, spoken only with raised fingers or the rap of a knife hilt against a gas bottle. A diver's most urgent cry—Mayday—can be uttered only with four fingers or four raps of a knife hilt against a gas bottle, and the raps don't carry very far.

We desperately need a research program dedicated to the development of a reliable diver-to-diver communication system that does not encumber him with wires and does not compromise the performance of his breathing apparatus.

The divers will spend their first 10–15 min. in the water working against the clock on delicate assembly tasks and intricate two-hand coordination tests. These, as well as measures of whole body strength, are done pre- and post-dive, in the water, in an attempt to measure the degradation of man's performance during long exposure to cold water.

Once these tests have been accomplished, they can get on with their work. This can consist of any number of tasks related to the ocean sciences, salvage, rescue, marine biology, geology, sound and light propagation, installation of marine weather instrumentation, logistics and maintenance of underwater equipment.

By and large, this work is done with ordinary tools that can be found in any mechanic's tool box and with equipment that works well on dry land but invariably develops some ailment after immersion in salt water. We need to devote more human engineering talent to the development of special equipment and tools for use in this dim, weightless, corrosive world.

If the diver's work carries him into water much deeper than his habitat, his suit is compressed by the increased pressure until it becomes paper-thin and loses nearly all its thermal-insulation properties, and he gets cold faster. I have seen men shudder with an amplitude of 4 in. from the cold. It isn't painful; sometimes it's even funny and we laugh and shiver together, but a man's ability to do useful work under these conditions is severely degraded.

We need to develop a suit that does not tear easily as it does now, but still provides a good thermal barrier, regardless of depth. We need to develop a reliable, thermostatically controlled, electrically heated suit, and ultimately we need to develop and adapt the liquid-cooled Apollo suit to our use. The liquid flowing through the

garment could be heated with a small radioisotope package replacing one weight on a diver's belt.

The astronaut's EVA chest pack and the diver's breathing apparatus are a study in contrasts. The chest pack is a beautifully designed, compact, miniaturized unit. The best of this country's talent went into its construction. The diver's lung, on the other hand, is an 84-lb albatross around his neck.

Monitoring the satisfactory performance of the lung currently in use is purely subjective, is done mainly by the diver's companion, and is limited to watching whether bubbles are coming from the right place or the wrong place. It is both difficult and time-consuming to set up the control element properly. It gets out of calibration easily, and is not as reliable as it can be made. It has many design defects and reflects very little of the tremendous advances recently made in the field of human engineering that are so evident in aircraft spacecraft, and space-age personal equipment.

The astronaut in flight faces a splendid panel of instruments which provides immediate and continuous evaluation of all the components and systems upon which his security depends. In addition, he has three shifts of eyes and ears around the world helping him, through telemetry, to check his equipment. The diver, in contrast, has little or no instrumentation in or out of his habitat. And, when he is in the water, he is alone. He and his companion are completely beyond the help of any man.

We do have some safeguards. For instance, a man can help his buddy get back home with an extra mouthpiece on his own equipment, but the need to give the diver better equipment, more instrumentation, and longer and deeper excursion times still exists.

Our most imaginative thought must focus on the design of the habitat and the whole concept of undersea living. Man must be able to sever his psychological, as well as his physical, ties to the surface. Adaptation of nuclear power would give us a completely autonomous, self-propelled research vehicle. It would avoid the many problems we face when we try to handle a sub-surface object with a surface vessel, and it would open up unprecedented depth and endurance capabilities.

The Sealab II habitat was luxurious in many respects, with larger portholes and wall-to-wall carpeting, but we are not served well by a cylindrical design. We need more room in the diving station; this was our worst bottleneck. We need telescoping legs to help us level it on uneven terrain, and separate laboratory areas away from traffic and we need crygenic oxygen storage.

Meanwhile—back to the aquanaut. He reenters his topside world not in a 15-min. blaze, but by purging his body slowly, and sometimes painfully, in a decompression chamber. A man remaining at 650 ft. must wait six days to step outside the chamber. In Houston, we have the

Free World's largest altitude chamber, capable of accepting the entire Lunar Excursion Module, Command Module, and Service Module.

For undersea work, we have a scattering of small pressure chambers around the country. One goes to 800 ft. We need a 200-ft. capability now, with a large, water-filled compartment which will allow us to evaluate the immersible equipment. It must be capable of being pressurized with helium, argon, or other rare gases as the need arises, and in it we need to study the effects on man of very high pressures.

Does he slow down, become sluggish? What cellular changes occur? How are his organic functions altered? A marriage of cellular chemistry and definitive physological and psychological studies, which is so badly needed, could center around a deep-submergence center with a high-pressure facility such as this. Accurate measure of caloric intake and metabolic rates could be made and valuable data gained by men interested in hyperbaric medicine.

Perhaps the chamber's most important use would be in the study of inert gas uptake and elimination by the human body. We must have a better understanding of this before we really begin to understand the decompression and narcois problems you've heard so much about.

I'm convinced that the press and TV sold the space program to the world. One of my chief regrets is that we could not bring back better photographic documentation from Sealab, but the light level and visibility just didn't permit it. These pictures would have been of great value in attracting more support and more young, intelligent, hard-driving men into our group of 50.

The disparity between the equipment used by aviators and divers is incredible, but pilots are a very powerful group, irritatingly so at times. Nevertheless, the have complained and fought for and gained the innovations and safety precautions that the undersea program needs now to move out of the "Gee whiz, we did it" stage.

I know the talent is out there. I know there are men looking for a field to which they can commit their lives.

In addition to our concrete list of needs, there is something else, something intangible that is worthy of mention. I think it narrows down to a basic feeling among the participants in these modern sustained experiments that we want more than just to remain alive. Our cry is "Make it better, make it last longer, make it easier to operate." After the feeble beginnings of pushing body and mind, and figuring out a way to beat the odds, we *always* want more.

An airplane that bears this nation's emblem, a spacecraft that carries the colors of our country around the globe, and a United States research vessel embarking on a mission in the depths of the world's oceans—all must be stamped superb.

The resources and men to make them so are available. We can be content only if we bring the best to coming operations. ■

SYSTEMS MANAGEMENT IN AEROSPACE

Astronaut preparing to erect S-Band antenna on lunar surface for TV transmission to earth. Artist rendering by Craig Kavafes, GAEC.

. . . A Grumman Challenge

■ Before we turn the corner and step into 1970 it is likely that the United States will have placed a man on the moon and returned him to earth. When that event takes place it will eclipse in scope all engineering accomplishments of the past.

As of the moment, this gigantic project, called Apollo, will cost the U.S. about $20-billion and will involve the highly demanding and coordinated efforts of roughly 5,000 industrial firms and 300,000 scientists, engineers, and technicians. But numbers alone cannot tell the story; they rarely can. Accomplishments that today lay at our doorstep must be related to the sweep of recent history if they are to be placed in perspective.

For example, it was just 36 years ago that the fledgling Grumman Aircraft Engineering Corporation, with six directors and 15 employees, fulfilled its first contract, the delivery of two amphibious aircraft pontoons. It was a modest beginning, but within three years Grumman had built its first bi-wing fighter plane and was thinking of expansion and diversification. Business grew steadily. Then the Second World War hit. Employment leaped. So did production: Some 17,000 planes were produced during the war, a feat that earned five production awards from the Navy, a Presidential Medal of Merit for Board Chairman Roy Grumman.

Those 17,000 planes, of course, weren't built by the original 15 employees who had turned out the two pontoons a few years earlier. But, even as employment burgeoned, the firm retained the small, family type atmosphere that still marks it as "a good place to work."

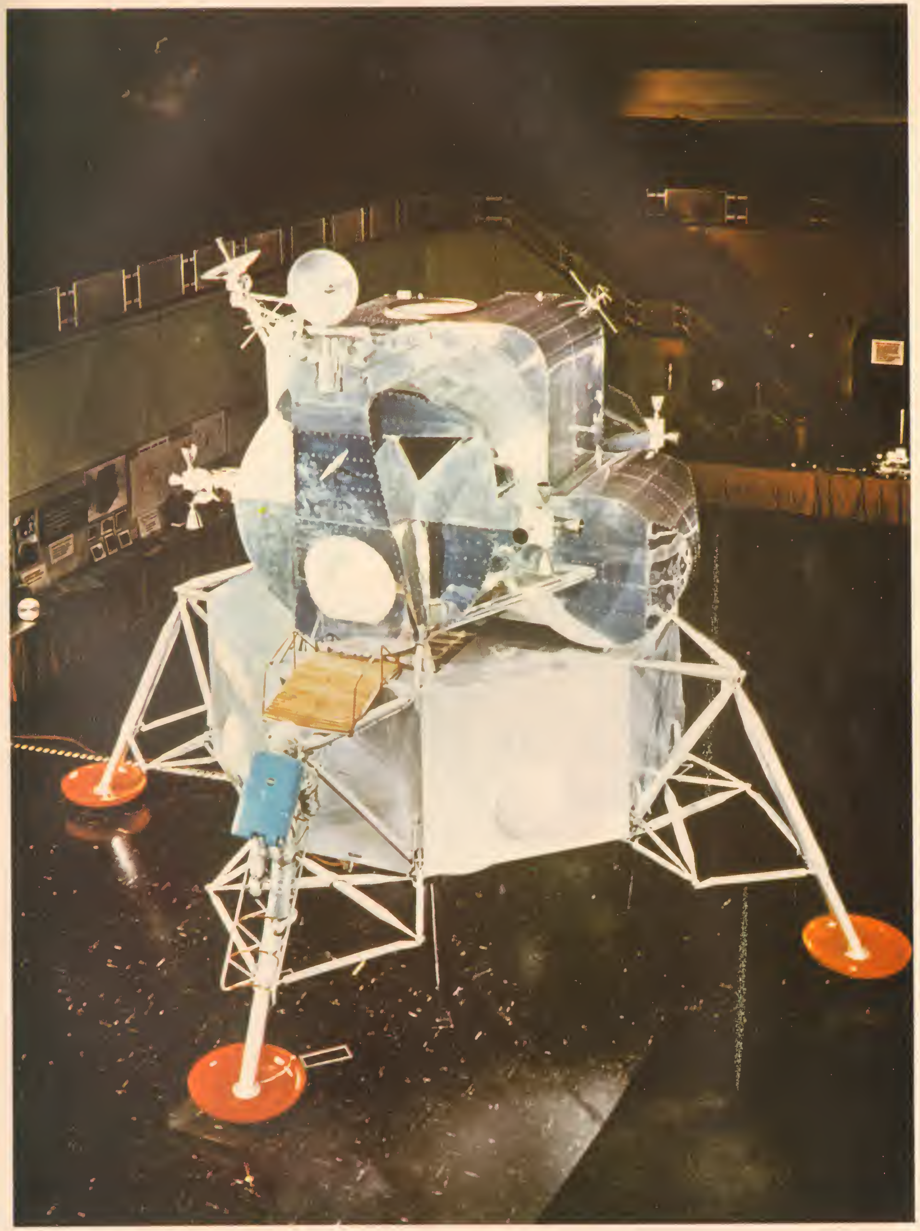
New management techniques were on the way, however, occasioned by the changing nature of the firm's undertakings. Suddenly there was a new scientific and industrial environment in which to operate.

New techniques and devices sprung up: electronically controlled communications systems, supersonic aircaraft, missiles, radar, sonar, cryogenics, microminiaturization, lasers, thermonuclear weapons, rocketry, and a host of others. They came not slowly or warily. They came as though impelled to overturn patterns of the past —with one sizzling streak of lightning.

An unmanageable flood of scientific data resulted. No one man had even the slightest chance of comprehending, much less directing, the stream of knowledge.

The era of specialization and sophistication was here.

New techniques of operation and management had to be created. Specialists were drilling deeper and deeper into knowledge, but there was a real danger that they would become insensitive to specialties not directly related to their own. A multiplicity of highly specialized disciplines scattered about without regard to analysis of their interrelationships was nonsensical: maximum thrust of knowledge could be



As a vehicle, the Lunar Module looks an unlikely candidate to carry one person to the corner drugstore. Within a couple of years, however, it will carry two men to the surface of the moon. The LM folds snugly into a flared fairing on the bottom (at launch) of the Apollo capsule. In orbit about the moon, two men will leave Apollo to enter the LM and descend to the lunar surface.

achieved only by close communications and organization plus firm management direction. The way to get that thrust is to adopt systems engineering, which, in its simplest form, means to plan and divide work in such a way that a desired objective is reached with a minimum of time and energy.

Grumman's work in designing and fabricating the Lunar Module, the Apollo vehicle that will land men on the moon, is a good example of the concept of systems engineering in practice. In essence the problem was how to produce a module that would be capable of carrying two men to the moon's surface and back to an orbiting Command Module.

The spade work began with a concept, an idea of what would be necessary. It came in the form of a Grumman interoffice memo in 1958—a full four years before companies were asked to compete for the contract by the National Aeronautics and Space Administration. In other words, work was begun at Grumman before most people were considering such a scheme. That foresight, and the willingness to commit $4-million worth of engineering dollars to an idea yet unproved—that calculated risk—later paid off. When the Government pressed for faster action in the space race in 1961, the Company *already had in hand* an exhaustive study of what is now labeled the Lunar Module.

The first step in the formulation of that study was to define the overall mission: to get a man on the moon and return him to earth. Then this broad mission was dissected and broken down into concrete and manageable segments. These elements are called systems which are complexes of functions that may or may not include equipment and machinery. In any event, these elements are the basic units of systems engineering.

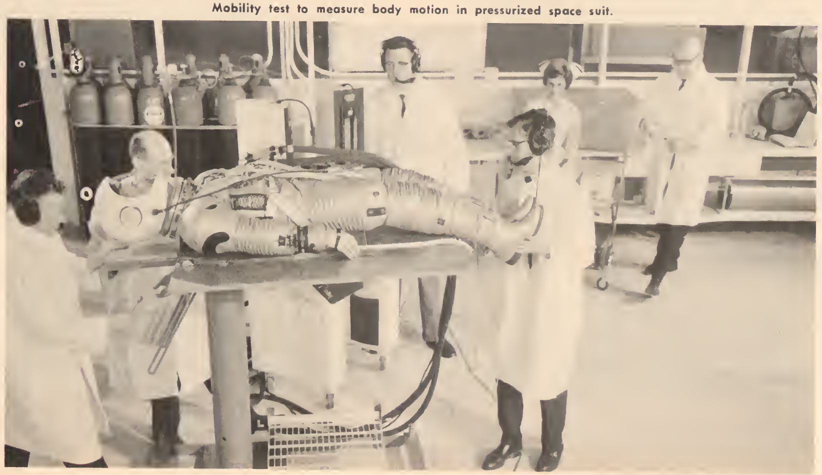
The management task is then to organize all of the pieces of the engineering puzzle into a coherent whole so as to accomplish the total mission. This management structure, if one were to view it as an isometric drawing, would be a pyramid. At the top, in the case of the LM, is a vice president. Immediately below is a program manager and an engineering manager, each of whom has administrative staff to assist him. As the chart fans out there are 9 program managers whose job is to oversee, direct, and control operations of the engineering and technical staffs in their broad functional areas. And the further down the line one goes, the more technical and specialized the work becomes, and, therefore, the broader the base of the pyramid.

All of these defined, specialized areas are systems shaped to solve the puzzling engineering and technical questions within their jurisdiction. For example, one system dealt with the human factors involved in matching equipment to the men using it; another dealt with vehicle structure, its flight characteristics and control, and temperature control; and yet another dealt with the integration of all of the complex parts that had to be fitted into a practicable whole.

Finally, at the broad base of the pyramid, were 10 major subsystems. These are concerned with hardware: the physical equipment necessary if the Lunar Module is to accomplish its mission. Subsystems managers direct and oversee a host of concerns, including source of power supply, descent and ascent stages of the moonship, earth-parent vehicle-Lunar Module communications, internal (LM) monitoring of systems, cabin environment (oxygen supply, pressure, temperature), crew provisions, and so on.

The pyramid that has been described, of course, is at best only an inner-visual hint or picture of structure, of overall organization as

Mobility test to measure body motion in pressurized space suit.



you might see it on an organization chart. There's some danger in oversimplifying it that way, however, largely because of two factors. First, the vertical and horizontal lines that make up an organization chart cannot be looked upon as blocks of duties and responsibilities set in concrete; rather, they must be viewed as guidelines for management control *only*. And second, not only is it possible to cross lines—to jump, say, from electronics to reliability—but such cross pollination is encouraged; maximum interplay between disciplines is essential, in fact, to good communications and clear visibility. In the last analysis, then, any man at any level of responsibility is free to consult with any other. The only restriction is what the industry calls "the need to know".

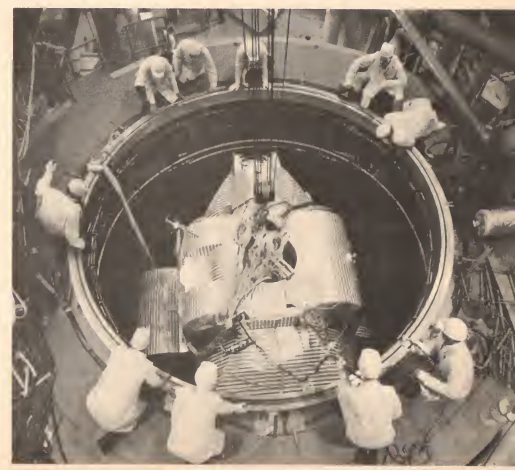
To put this in another way, the traditional line-staff relationships no longer hold. The emphasis today is on different factors, such as specialization, the birth of new ideas, flexibility, and intercommunication (not only within a company but in cooperation with other firms). The scope is virtually unlimited, as are the opportunities. It is truly a fast moving world, one in which yesterday's solutions swiftly become obsolescent and then obsolete, replaced by new solutions that will follow the same route. It is the price—and the heady reward—of a racing science.

It is sometimes frustrating, too; for design changes keep coming in, virtually to the day that the product goes out the door, completed. And there are "little" problems that suddenly mushroom into large ones. For example, engineers tortured their brains for a couple of years in an effort to solve one of those "simple" problems: a vehicle seating arrangement that would also allow the astronauts to view their descent path by looking through windows of the Lunar Module. The original LM design, created by NASA strictly for the purpose of an industry-wide competition, called for four glass windows with a total area of 13 ft^2. Subsequently, this proved unfeasible primarily because the glass was too heavy. The design also limited basic pressure reliability. In addition, seats took up too much space and weight. One day a NASA engineer made a comment that led to a simple solution: if the astronauts *stood up* during their hour-long descent there would be no need for seats. This permitted the astronauts' faces to be closer to the windows, which then could be much smaller. A simple problem simply solved!

And so it goes day after day, the little twist that makes the big difference. There'll be more little twists before that half-million mile round trip is chalked up on the board of history. It's an exciting business that leads one to wonder: are we in the middle of a scientific and technological revolution, or are we only taking our first baby steps into a world we are yet too young to see? ■

At 50,000 ft. in altitude simulator, Plant 31, test subject is being closely monitored via TV at bio-medical console. LM Environmental Control System is tested at various simulated altitudes.

LEM TM-2 Ascent Stage being lowered into Thermal Vacuum Chamber for testing heat dissipation properties and reaction of its equipment to extremes of heat and cold. Painted stripes were added to vehicle to give skin surfaces the desired emittance coating.



MAN AND THE SEA

(Continued from page 48)

either air- or hydraulic-lift principles should be usable to water depths of 1000 ft. or more.

The question of how much of a mineral hoard exists in the sea is virtually unanswerable at this point, and awaits a very specialized exploration of the ocean bottom. New types of deep-diving submarines and surface ships, improved free-diving equipment and facilities, and better sonar and optical imaging systems all will be required before any reasonable estimates as to the volume of minerals available and the quality of the ores found can be made.

However, these is little doubt about the fact that, sooner or later, as the cost of extracting and processing minerals from low-grade ores grows higher, there will be an ever-increasing tendency to explore what appear to be favorable ocean areas. It should be recalled that man has actually mined the sea since time immemorial, extracting salt from it. And beach deposits of gold, silver, platinum, tin, diamonds and other minerals, have been mined commercially in a few areas. The diamond mines on the western coast of South Africa are but one example.

The continental shelves offer immediate possibilities of some new commercial harvesting of minerals, particularly phosphate nodules, which may be of interest as a possible new source of fertilizer. Manganese nodules are found in the deeper waters, usually at 16,000–18,000 ft., and apparently cover many areas throughout the Pacific, as well as some Atlantic areas. Some experts feel that these may become economically attractive within 10 years.

Thus far, we have been talking about the economic benefits to be derived from the sea. However, it is quite obvious that the sea is of enormous military importance as well. As Adm. David L. McDonald, Chief of Naval Operations, recently put it: "We must be able to operate with increasing effectiveness beneath as well as on and over the seas, and concurrently develop instruments to detect submarines at long range as surely as we now detct surface ships and aircraft."

Solving just this one problem is not nearly so easy as it sounds. In fact, it sometimes appears that the oceans have gone out of their way to make it as difficult as possible for the Navy to achieve this purpose.

To begin with, many of the sea's physical properties, and phenomena such as waves, tides, currents and turbulence, electromagnetic and infrared characteristics, radioactivity and optical properties, have implications for equipment design and must therefore be thoroughly investigated. This requirement in turn demands the development of special instrumentation to measure these properties and phenomena.

For example, the sea is layered to an extent which is seldom appreciated, and it has been found experimentally that the transmission of sound is better over certain of the sea's "channels" than others. In other words, there is such a thing as "good" sonar water, through which submarines tens or even hundreds of miles away can be detected—provided, of course, that the right kind of listening equipment is available. Matching the size of the underwater "ear" to the wavelength being listened to is a very complex design problem.

However, it is obvious that increasing the range at which enemy submarines can be detected depends on extensive knowledge of the sea's physical characteristics and how to predict changes in these characteristics, and an intensive Navy effort is being devoted toward this end.

Although we have only scratched the surface here, it is obvious that an enormous range of talent is required to build underwater technology to a point where man truly begins to *conquer* the sea. It is not merely, or only, an engineering task. It is an exceptional example of a truly interdisciplinary effort, which brings together all of the physical sciences, the life sciences, and even some of the social sciences, as well as engineering science and technology.

One of the things which has been so impressive about the underwater technology effort is the way men with so many different backgrounds have banded together to take on this most difficult job. It is necessary. It will be done. ■

opportunities

in sales engineering

David Retzinger

■ Recruitment of undergraduate engineering students for technical selling careers is highly competitive and today has become an even more important sales function in many firms.

There are sound reasons for this special recruitment effort. First of all there's a great need for sales engineers, and secondly, many of the engineering students still do not understand the requirements and nature of technical selling. Many undergraduates still can not visualize the opportunities that selling affords as a life's work. There are also students who are not aware of the fact that many of the top executives in engineering and manufacturing firms succeeded because they started their carreers as sales engineers.

In our own recruitment program, which we analyze every year, we have learned that it is rather difficult to hire a young engineer, and try to direct his abilities into a sales career. After he acquires a knowledge of the many benefits that selling provides, there is a complete change in attitude. We have come to the conclusion that resistance to selling is principally due to the lack of real understanding and knowing how challenging technical selling really is in comparison to the other engineering positions —application, project, research and development, and others.

Technical selling does offer an engineer personal advantages which can be so easily overlooked. Naturally, selling is a glamorous career, and financially it has unlimited boundaries. It provides plenty of opportunity for advancement into top management jobs. Then, too, a sales engineer is quite a different specimen, because he has had the need to develop his abilities to an optimum, such as, imagination, creativity, perseverance, friendliness and cooperativeness.

A sales engineer is proud to be a salesman. He not only sells the product, but is a disseminator of ideas that develop lasting business

Dave Retzinger, vice president of sales, Perfex Corporation, Milwaukee, Wisconsin, has served in sales engineering for more than 15 years and has held many top-echelon sales positions in his interesting career. He has written this article to encourage engineering students and graduate engineers to take a new look at technical selling as a challenging, stimulating and rewarding career.

Dale Fischer, right, sales engineer, Perfex Corporation, discusses construction of his company's condenser coil used on an air-cooled type air conditioner with Richard Signorelli, manager of manufacturing for the Climatrol Division of Worthington Corporation.

friendships. To a great extent he is his own boss. Often, he is a leader in his community because economically he approaches the professional classes—doctor, dentist, lawyer, professor, architect, etc. In many instances, his earnings average in the top management groups. What's even more important, he will always be in demand. He lives a stimulating life.

The usual impression a student has of a salesman is that conveyed by the Broadway play, "Music Man." In other words, the young engineer has the impression that a salesman is a happy-go-lucky individual who is always on the move, has an unlimited supply of jokes, wears loud clothes, and is always trying to sell a prospective customer something he really doesn't need, and for a price he really cannot afford to pay.

Contrary to these common impressions, sales people cannot be categorized. In every day living, all of us do sell in one way or another. Cooperation between two individuals in any kind of endeavor requires some selling. Therefore, whether we realize it or not, everyone is a salesman at one time or another. Specifically, a sales engineer directs and consciously improves his natural sales ability to the point where he focuses his imagination, intelligence, and creative ability on a specific problem of a technical nature, which will benefit his prospective customer.

And, when a graduate engineer completes his training course and begins his career as a full-fledged salesman, he finds that he has greater freedom than most company employees. He is seldom away from his family for long periods of time. Most companies do not have their sales engineers "on the road" more than five consecutive days. The sales engineer, in his effort to solve engineering problems, has the opportunity to travel widely, normally under first class conditions. Not only does this travel bring him into contact with his customers, but it gives him an appreciation for customs, problems, and ways of living of many individuals, and also the opportunity to exchange ideas with individuals other than those in his immediate community.

The selling process usually involves the solving of a customer's problem in a better way, or at a lower cost, than the customer previously believed possible. It involves the imagination and creativity of the sales engineer to the application of his company's product in solving his customer's problems. In other words, the salesman is a progress maker. Many times, because of the sales engineer's experience and association with many different industries and facets of industry, because of his wide travel, and because of the imagination and creative ability developed through the selling process. he comes up with ideas for products which are needed in the market place to solve specific desires or requirements of the market place. He, therefore, becomes a source of products, or ideas for products, for his company.

In my opinion, the better an engineer is in his engineering profession, the better sales engineer he will be. The sales engineer is normally dealing with other engineers, and they expect him to thoroughly understand his product as well as their problem, and to relate the solving of their problems to his product. He must be able to communicate his ideas to his prospective customer, and show the prospective customer where a better product or a better solution to the problem will result by application of the product he represents.

The company's success starts and finishes with the customer, and the go-between is the sales engineer.

opportunities in application engineering

G. L. Taft
Manager, Application Engineering
Industrial Compressor Dept.
Joy Manufacturing Co.

■ What is an Application Engineer? Perhaps the easiest and clearest way to define what an Application Engineer is, is to first say what he is *not*. He is *not* a *Design Engineer* and is not in the Engineering Department in most companies. He is *not* a *Sales Engineer*, not being in the Sales Department and not usually calling on customers. He is *not* an *Industrial* or *Manufacturing Engineer* since he is not in the Manufacturing Department. Since these are the major three departments of any manufacturing concern, then where does he fit? Our answer is right in the very middle. In other words, he is in the center of activity which reaches out to the other three areas—Engineering, Sales, and Manufacturing.

Let us proceed to describe what his functions really are . . .

(A) Apply the product to the application.
(B) Analyze the cost and assign a price which will prove profitable to the company.
(C) Support the Sales Department with sufficient technical information to sell the product through the following means:
  (a) Price Book
  (b) Sales Manual
  (c) Sales Literature
(D) Miscellaneous other duties such as other supplying management with sales forecasts, profitability plans, new product studies, and analyses of lost business reports.

There is no universal term for this group. In some companies the department is called the Product Department, others Marketing Services Department, others Application Engineering Department.

The Engineer who enters this department may come in from college, from another company, or from one of the other operating departments of the same company. His desire, of course, is to get a broader knowledge of the over-all company operation. Frequently, sales engineers, disenchanted with the glamorous life of the salesman, the long hours away from family, but still with a flair for being of service to other salesmen and customers, have the proper attitude for this department, and may grow as rapidly as the fellow salesman who stays in the field.

On the other hand, a trainee in the Product Department can get his feet on the ground for application engineering and go into the sales department with sufficient technical knowledge to develop into a fine field salesman and district manager. Design engineers with inclinations toward sales can first come into the Product Department before going into the sales and have a very strong background for growth in the company. All these are areas where an engineer has passed through the application engineering group.

However, there certainly is an opportunity for the man who wants to make a career of application engineering to contribute heavilly to the success of the overall operation by thorough training in cost accounting, design engineering, sales engineering, and combining them to the fullest extent in the forward look of the company.

Educational requirements are, first, a degree in Engineering in the field of which the company is engaged. In other words, heavy machinery should have a Mechanical Engineering degree. As an alternate, Industrial or General Engineering degree would be acceptable, in fact, desirable, when a business minor is a part of the course. Of course

there is a substitute for a degree in hard work, basic mathematic courses, and a drive to succeed without the degree recommended.

In a sense, the Application Engineer is the storekeeper of a corporation. Profit responsibility often rests in his hands. Poor application engineering means uncertain profitability, poor planning, and sometimes corporate failure. If any plant does not have a strong, aggressive, application engineering or product group, it shoul consider installing just such a distinct separate function.

The Product Manager would be not only a manager, but ideally an Application Engineer. He should be of the same high calibre as the other managers and able to guide the General Manager in making well-balanced decisions in the overall management of the company.

The ultimate goal for a capable Application Engineer is a top management post. The rewards certainly are as satisfying as any other branch of engineering.

Therefore, young engineer, or reader, consider making a career of Application Engineering.

INTERVIEWS on *YOUR* CAMPUS

The companies advertising in this issue have indicated their intention to conduct campus interviews at the schools under which they are listed in the following pages. However, don't hesitate to send your resume to any firm in whose advertised openings you are interested, whether or not they are listed under your school, as some arrangements for interview can usually be made. Further, recruiting schedules are subject to change and a check with your Student Placement Office may reveal that a company *not* listed here will be interviewing on your campus. Use the handy Inquiry Form on Page 129 to notify firms of your interest and get your interview scheduled in advance.

Academy of Aeronautics
Grumman Aircraft Engineering Corporation

Akron, Univ. of
Air Force Systems Command—Aeronautical Systems Div.
Allis–Chalmers
Field Service & Support Div. Hughes Aircraft Co.
McDonnell Co.
System Div. Wright Air Force Patterson, Ohio
U.S. Navy Ship Systems Command
Western Electric Company, Incorporated

Alabama
Air Force Systems Command—Air Proving Ground Center
The Boeing Company
Lockheed Missiles & Space Company
Northrop Corporation
Olin Mathieson Chemical Corp.
Rohm and Haas Co.
Western Electric Company, Incorporated

Alabama College
Air Proving Grd. Ctr. Eglin A.F.B., Fla.

Alabama State College
Air Proving Grd. Ctr. Eglin A.F.B., Fla.

Southern Alabama, Univ. of
Air Proving Grd. Ctr. Eglin A.F.B., Fla.
Ford Motor Co.
LTV Aerospace Corporation
McDonnell Co.
USDA Forest Service
U.S. Navy Ship Systems Command

Alaska, Univ. of
The Boeing Company

Albion College
The Rauland Corp.

Albuquerque, Univ. of
Air Force Systems Command—A. F. Special Weapons Center

Alfred Tech
Dresser Ind., Inc.—Dresser Clark Div.

American Institute of Foreign Trade
Allis–Chalmers
Olin Mathieson Chemical Corp.
Rohm and Haas Co.

American Univ.
National Institutes of Health

Amherst
Rohm and Haas Co.

Amos Tuck
Western Electric Company, Incorporated

Arizona State Univ.
Air Force Systems Command—A. F. Missile Development Center
The Boeing Company
Collins Radio Co.
Fairchild Semiconductor
Lawrence Radiation Laboratory
Lockheed Missiles & Space Company
Naval Civil Engineering Laboratory
Naval Ship Engr., Center of Calif.
Northrop Corporation
Philco WDL
Sandia Corporation
San Francisco Naval Bay Shipyard
U.S. Naval Civil Engr. Labs of Calif.
Western Electric Company, Incorporated

Arizona, Univ. of
Air Force Systems Command—A. F. Missile Development Center
The Boeing Company
Collins Radio Co.
Fairchild Semiconductor
General Dynamics—Convair Division
Lawrence Radiation Laboratory
Lockheed Missiles & Space Company
LTV Aerospace Corporation
Naval Civil Engineering Laboratory
Naval Ship Engr., Center of Calif.
Northrop Corporation
Pan American World Airways
Philco WDL
Radio Corporation of America
Sandia Corporation
San Francisco Naval Bay Shipyard
TRW Systems
U.S. Naval Civil Engr. Labs of Calif.
Western Electric Company, Incorporated
Western Gear Corp.

Arkansas, Univ. of
Allis–Chalmers
Cessna Aircraft Co.—Commercial Div.
Cessna Aircraft Co.—Military–Twin Div.
Chrysler Space Div.
Collins Radio Co.
Fairchild Semiconductor
LTV Aerospace Corporation
McDonnell Aircraft Corporation
McDonnell Co.
Olin Mathieson Chemical Corp.
Rohm and Haas Co.
Sandia Corporation
USDA Forest Service
U.S. Navy Ship Systems Command
Western Electric Company, Incorporated

Atlanta Univ.
National Institutes of Health
Sandia Corporation

Arlington State College
Air Force Missile Div.—Halloman Air Force Base, New Mexico
Air Force Systems Command—A. F. Missile Development Center
Cessna Aircraft Co.—Military–Twin Div.
Collins Radio Co.
LTV Aerospace Corporation
Western Electric Company, Incorporated

Auburn Univ.
Air Force Systems Command—Air Proving Ground Center
Air Proving Grd. Ctr. Eglin A.F.B., Fla.
Allis–Chalmers
The Boeing Company
Charleston Naval Shipyard
Collins Radio Co.
Fairchild Semiconductor
Lockheed Missiles & Space Company
The Martin Co.
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Northrop Corporation
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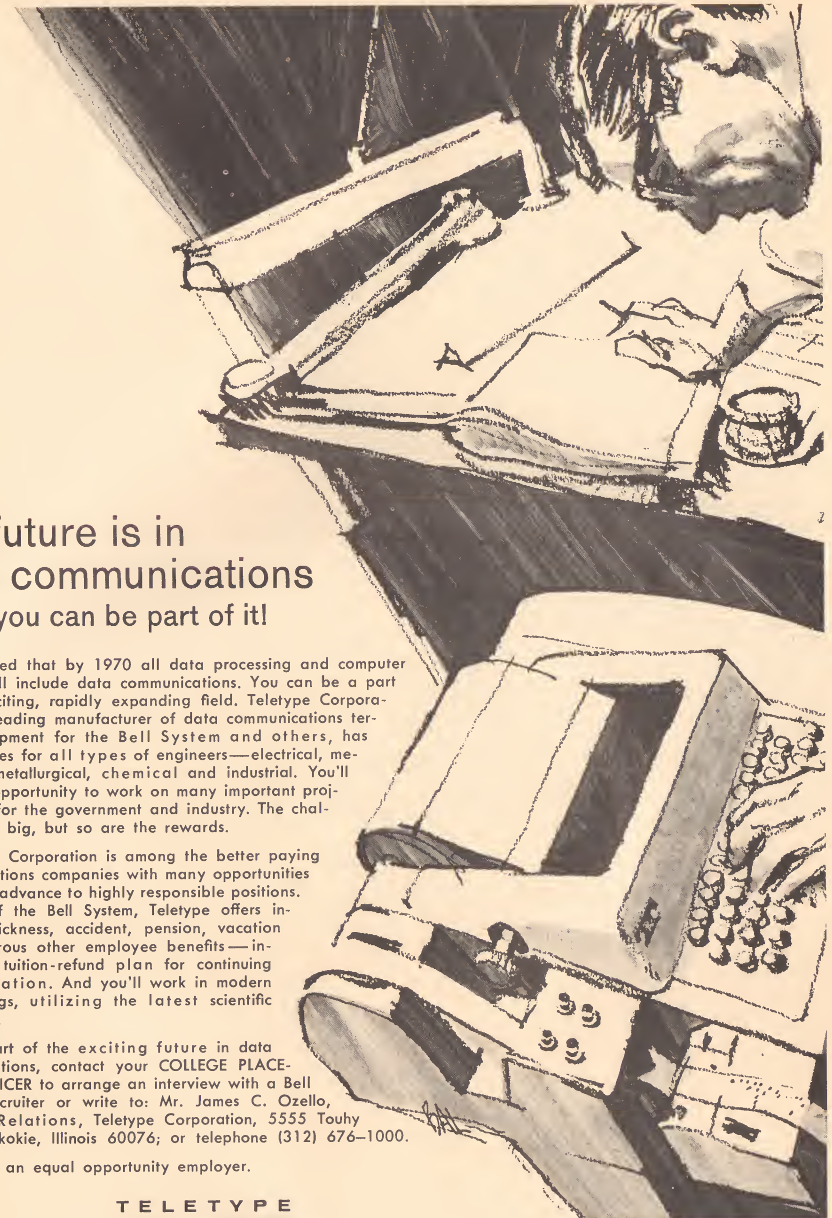

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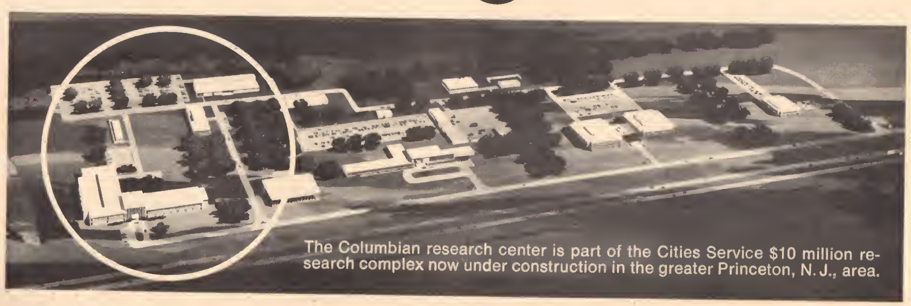

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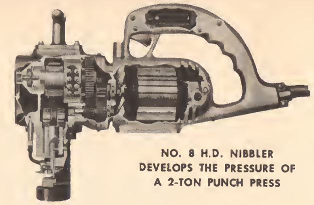

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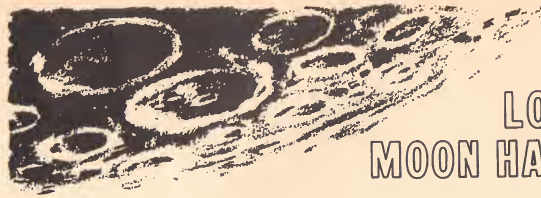

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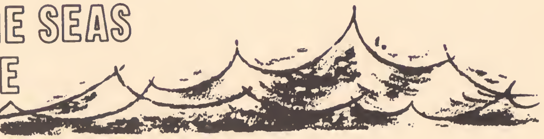

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